cular volumes of a long series of normal paraffins, made on the liquid substances at temperatures at which the materials are in physically similar conditions, are stated in column 4. Since the valency of carbon is four times that of hydrogen, it would be anticipated from the crystallographic conclusions previously drawn that each carbon atom should appropriate four times as large a space for occupation as one hydrogen atom; the quotient of the molecular volume by the valency sum or valency volume, W, should consequently lead to the same value, S, in the case of all the hydrocarbons. The mean value of S, namely, the atomic volume of hydrogen, is thus calculated as 2·970, and that it is constant within very narrow limits is seen on comparing columns 4 and 5, the latter of which states the product of the valency volume, W, by the value 2·970. The simple relation between the atomic volumes of carbon and hydrogen in the liquid normal paraffins indicated in the above table was recently pointed out by Lebas, and is abundantly confirmed by numerous series of determinations in addition to that now quoted. It is thus definitely proved that the law of valency volumes, first enunciated on the ground of the crystallographic evidence, holds rigidly in the case of these liquid substances.

Sufficient has been said to demonstrate that a method has now been devised by means of which the vast stores of accurate goniometric measurements collected by crystallographers during the past century can be interpreted, and that the requisite interpretation has in many cases already been given. Prof. Liveing, in a discourse delivered in this room nineteen years ago, suggested that crystalline forms are the outcome of the accepted principles of mechanics; the aid of these, and of these alone, has been invoked to show that crystalline structures result from the equilibrium of the attractive and repulsive forces radiating from the atomic centres.

RESULTS OF SOME RECENT INVESTIGATIONS ON MAGNETIC DISTURBANCES.[1]

AN examination of the times of beginning of the magnetic disturbance which occurred on May 8, 1902, as coincidently with the Mont Pelée eruption as can be determined, revealed the interesting fact that they were not the same all over the globe, being, in general, earliest at European stations. The times next progressed going around the earth eastwardly, the complete circuit being made by the disturbance in about $3\frac{1}{2}$ minutes. This fact led to an examination of other similar disturbances, such as the one of January 26, 1903, and it was again seen that this one also progressed around the earth eastwardly, the time for the complete circuit being about 4 minutes.

Mathematical analyses were next made, and it was found that for both disturbances (May 8, 1902, and January 26, 1903) the systems of disturbance forces which it would be necessary to superpose upon the earth's own magnetic field were precisely of the same character as the earth's. In other words, were we to assume electric currents as constituting the disturbance systems, then, as is the case for the earth's field, the currents would have to circulate around the earth from east to west if they are positive ones, and in the contrary direction—from west to east—if they are negative or such as would be produced by moving negative charges. Furthermore, for both disturbances the electric currents would have to circulate chiefly in the regions above the earth.[2]

For the disturbance of May 8, 1902, there were a sufficient number of trustworthy determinations of the effect on the vertical intensity, and accordingly it was possible, by means of the analysis, to separate the external system of currents from the internal (below the surface) one; and then the surprising result revealed itself that the internal currents went in the same direction as the external ones, the latter being about three times the strength of the former. Hence, were we to suppose that the disturbance is caused by the motion of negative charges around the earth eastwardly, then the internal negative currents also go in the same direction, and accordingly they are not currents induced in the earth by the outer system.

If the earth's own magnetic field is likewise separated into an internal system and an external one, it is also found that for both systems the negative electric currents go in the same direction around the earth, viz. from west to east. The disturbance systems found above are therefore precisely similar in character to the earth's field. It should also be noted that the negative currents of the disturbance progress around the earth in the same way as did the times of beginning referred to above.

We have now become acquainted with the fundamental facts of observation pertaining to the simplest class of magnetic disturbances experienced by the earth—the sudden beginnings of magnetic perturbations, which, in accordance with van Bemmelen's suggestion, we will term for brevity "S" storms. Let us see what hypotheses are necessary for a *physical* explanation of the observed facts.

Prof. Kr. Birkeland, of Christiania, was the first to have attempted a definite physical theory to account for this class of disturbances, which he termed "equatorial perturbations," since they are most strongly developed in the equatorial regions, as judged alone from the size of the disturbance effect on the horizontal intensity. If the latter element suffered an increase, the disturbance was called a "positive equatorial perturbation," and if, on the other hand, the horizontal intensity was decreased, the disturbance was termed a "negative equatorial perturbation." The theory for these particular disturbances is only a part of the general "kathode-ray theory" developed by Birkeland and Störmer to account for all classes of magnetic disturbances and of polar lights, as set forth in their various papers, and especially in Birkeland's recent publication, "The Norwegian Aurora Polaris Expedition, 1902–3," vol. i., "On the Cause of Magnetic Storms and the Origin of Terrestrial Magnetism." It will be noted that it is even hoped to build up a general theory of terrestrial magnetism, and there is an intimation that the earth's magnetic periodic variations may likewise be among the consequences of kathode rays coming from the sun and entering the earth's field.

Without question, these important contributions of Birkeland and Störmer mark a distinct advance, and the student of magnetic science will find not only incentive, but also a wealth of material and many suggestive facts by looking over these very valuable researches. At present, however, their theoretical results and deductions must be regarded chiefly as *qualitative*. While it is made very plausible that the cause of our magnetic storms is to be referred principally to kathode rays originating in the sun and coming within reach of the earth's magnetic field, there are a great many questions left open which will require answering before full acceptance can be given to the theory in all its details. How the earth's own magnetic system is affected by a magnetic disturbance—whether the intensity of magnetisation is increased or decreased, if there are any after-effects, whether the currents within the earth are induced ones or are the same in direction as those outside, &c.—are but a few of the interesting and important questions to be solved.

It seemed very desirable, therefore, that someone should take up the investigation from an *analytical* point of view, viz. to take a typical magnetic storm and analyse the observed effects into spherical harmonic terms, so as to determine just how much is due to outside currents and how much to currents within the earth itself.

Birkeland concluded, from a general consideration of the effects of a magnetic disturbance on the vertical intensity, that all storms originate from without, and it is quite possible that, in the main, he may be right, but the conclusion cannot be accepted as invariably true without a detailed mathematical analysis of each particular case. In his first volume he accordingly proceeds on the assumption

[1] A summary of two papers presented respectively at the meeting of the Washington Academy of Sciences, February 17, 1910, and at the meeting of the Philosophical Society of Washington, April 9, 1910.

[2] See *Terrestrial Magnetism and Atmospheric Electricity*, vol. xv, pp. 9–30. In this connection it is also well to record that Dr. W. van Bemmelen, in his recent investigations on "The Starting Impulse of Magnetic Disturbances" (Proceedings of the Amsterdam Academy of Sciences, April 24, 1908), found the following important fact as applying to the Batavia magnetic observatory records, 1882–99:—"Taking no consideration of the slight introductory movement, 124 cases furnished for the duration of the impulse: in horizontal intensity, 4·5 min.; declination, 3·2 min.; vertical intensity, 12·0 min. The duration of the vertical intensity movement is in general difficult to determine, as the decrease in this element keeps on mostly much longer. It is important to notice that the initial movement of D stops or is inverted, whilst of H the increasing movement keeps on."

that by far the greater part of a disturbance is due to upper electric currents, though quite likely, in a subsequent volume, he will consider the subterranean currents also. Since the observed quantities actually to be operated with appear to be resultant effects of both external and internal forces, it is very desirable that we should know just what proportion must be referred to one cause or the other. For this separation we require, however, a knowledge of the disturbances in the vertical intensity, and these are either difficult to determine with sufficient accuracy or are not to be had always at a sufficient number of stations, so that Birkeland was perforce compelled in his first treatment to assume chiefly external currents.

It was for these reasons deemed desirable to make known promptly the deductions derived from the mathematical analysis of certain typical cases of the class of "S" storms. We have now the means of applying the first decisive tests as to how far the Birkeland-Störmer theory will account for the facts.

There is a distinct advantage in treating, for the present, simply these sudden beginnings of magnetic disturbances for the reason that not only the time of beginning can be sharply determined, but, what is equally important, the actual magnitude and direction of the disturbance effect on any particular element can be most accurately determined. As the effects we are here especially considering do not extend, in general, over five minutes, we may readily scale off on the magnetogram the disturbance effect, being, without essential error, simply the difference between the ordinate to the curve at the point of beginning of the disturbance and the ordinate to the particular point of the disturbance considered. When, however, a magnetic storm extends over many hours, and even days, and one wishes to know the magnitude and direction of the disturbance at stated times, for example, every hour or half-hour, then what is called a "normal curve" must be drawn from which the disturbance ordinate is to be measured. This "normal curve" is supposed to represent the curve of magnetic variations which would have resulted had there been no disturbance; but to determine such a curve is far more difficult than is generally realised, and usually an arbitrary assumption of some kind must be made to derive it. Of such assumptions we are practically free in the disturbances considered.

Application of Tests.

The first fact of importance found from the analysis of the disturbance of May 8, 1902, was that the direction of flow of the negative electric currents, which could account for the external and internal magnetic disturbance systems, was the same for both systems. While the strength of the external system was about three times that of the internal, nevertheless, the internal currents were not the direct consequence of the outside moving negative charges, *i.e. they were not induced currents.* Instead, for both systems—outside and inside the earth—the flow of electricity was eastwardly around the earth for negative charges and westwardly for positive charges.

Having fixed the direction of flow of negative electricity, let us inquire now whether kathode rays coming from the sun will give the required direction. Birkeland, in his experiments on a magnetised terrella when placed in a Crookes's tube and subjected to a bombardment of kathode rays, observed, among other interesting phenomena, the formation, under certain conditions, of a ring of kathode particles which encircled the terrella in the magnetic equatorial regions. For an unmagnetised terrella there was no such ring. Störmer, from his mathematical investigations, found under what conditions a similar ring would be formed when kathode rays from the sun came within the deflecting influence of the earth's magnetic field. The ring results when electric charges enter a magnetic field perpendicularly to the lines of magnetic force, *e.g.* in the magnetic equatorial regions. It was on account of the possible formation of such an equatorial ring that Birkeland was apparently led to the adoption of his term "equatorial magnetic perturbation," and to refer its cause to such a ring.

If we apply, however, the well-known law according to which a negative charge would be deflected if entering the earth's magnetic field from without at right angles to the lines of magnetic force, it is unfortunately found that the deflection is to the west, and the moving negative electric charges would accordingly encircle the earth from east to west, hence opposite to what our mathematical analysis of the disturbance of May 8, 1902, and January 26, 1903, have shown must be the case to account for the observed disturbances.

Were we to assume, on the other hand, that the corpuscles are shot up into the earth's field instead of downwards, then those which struck the lines of magnetic force perpendicularly would, after successive deflections, circulate around the earth from west to east or eastwardly, and hence harmonise with the observed facts. Thus far, then, we should have to conclude that if the disturbances considered are to be referred to kathode rays deflected by the earth's field into more or less circular paths, the source of the kathode rays would have to be within the earth itself, and not without.

But if the radius of the ring of moving corpuscles is computed to conform with the time of propagation of the disturbance around the earth (about $3\frac{3}{4}$ minutes), it is found that the orbit would have to be distant from the earth's centre 580 times the earth's radius, or 3,700,000 kilometres, or 2,300,000 miles, and thus the possibility of a terrestrial origin of the kathode rays is likewise eliminated. Furthermore, if we calculate the intensity of the current which at that distance could produce the observed effects of the disturbances of May 8, 1902, and January 26, 1903, it is found to be 5,900,000 amperes. Now Birkeland says on p. 311 of his book:—"In the case of the greater storms, we found current-strengths that varied between 500,000 and 1,000,000 amperes, or even considerably more." Hence, to produce the comparatively insignificant magnetic disturbance effects here considered, by supposing a band of kathode particles circulating around the earth, would require a current at least six times stronger than that which Birkeland finds sufficient to account for the much larger storm effects!

The hypothesis was next briefly examined on which the disturbance effects considered might be referred to alterations in the electrical conductivity of the atmosphere and of the earth, either brought about by the secondary effects from bombarding kathode particles, viz. the formation of Röntgen rays, or, say, by the entrance into the earth's field of the penetrating radiation (γ rays of radium). The ionising effect and resultant alteration of electrical conductivity of the regions involved might either be due to the penetrating radiation from the sun or from the earth, if only *qualitative* results are considered. It is therefore at present not possible to state definitely whether the initial cause of the disturbance of May 8, 1902, was due to a terrestrial eruption or a solar one. First, further examinations will have to be made of the disturbances of May 20 and July 9, 1902, which were again closely coincident with the Mont Pelée eruptions. The electric-conduction hypothesis appears to satisfy, in general, the observed phenomena, and accordingly it is to be subjected to a further rigid examination. It seems also to explain why some of the disturbances take a westward path, although the majority of them go eastward.

Were we to suppose that the generated currents lie on a sphere of radius approximately equal to that of the earth, a velocity of the moving negative charges of 180 kilometres, or 110 miles per second, results, hence a quantity of the order of that for metallic conduction, or as found for the kathode rays from glowing electrolytes.

In conclusion, it should be stated that while it has been shown that the class of simple disturbances discussed in this paper cannot be referred to kathode rays in the way Birkeland and Störmer have supposed, it should be distinctly understood that this in no wise vitiates other portions of their theory, especially with reference to the larger and more complicated magnetic disturbances and to the origin and formation of polar lights. Before anything definite can be said as to the validity of these portions of their theory, it will be necessary to await the completion of a similar analytical treatment to that made for the "S" disturbances.

Such an analytical examination the writer has had under way for more than a year, and a preliminary statement of results was made at the meetings of the American Philo-

sophical Society and of the American Pnysical Society in April, 1909. Instead of drawing curves showing the variations in the diurnal ranges of the magnetic elements with solar activity, as is most frequently done, curves were constructed showing the effects of the magnetic disturbances experienced by the earth during the period April, 1906, to December, 1909, at the Coast and Geodetic Survey magnetic observatories, on the absolute values of the magnetic elements, and especially upon the intensity of magnetisation. This latter curve had been drawn for the first time; when it was compared with the curves showing the variation in solar activity, during the same period, as manifested by sun-spot frequency, sun-spot area, and calcium flocculi area, then the interesting result was obtained that "the intensity of magnetisation of the earth in general decreases with increase in solar activity."

In other words, the average or residual effect of magnetic disturbances, in general, is equivalent to that which would result by the superposition of a magnetic system opposite to the earth's own field, *i.e.* a demagnetising or induction system of magnetic forces. The north magnetic pole of this superposed system is, in general, in high south latitude instead of high north latitude, as is the case generally for the small "S" disturbances already discussed.

Hence for the larger *disturbance systems,* the electric currents which we may suppose to cause the effects would circulate around the earth, for negative ions, from east to west, *i.e.* contrary to the negative currents for the "S" disturbances, but this time in strict accordance with the direction in which a kathode ray coming from the sun would be deflected by the earth's magnetic field.

For these big disturbances, accordingly, the times of beginning, if they can be accurately obtained, will show an increase going round the earth westwardly. A good example is the most remarkable disturbance of which there is any record, viz. that of September 25 last. Here are the times for two sudden deflections at the beginning of the storm, as scaled by Mr. R. L. Faris, of the U.S. Coast and Geodetic Survey, from the horizontal intensity magnetograms of the five Coast and Geodetic Survey magnetic observatories:—

No.	Station	Greenwich mean civil time Sept. 25, 1909 Impulse First	Second	I.–II.
		h. m.	h. m.	
(1)	Porto Rico	8 37·7 ...	11 39·8 ...	−2·1
(2)	Cheltenham	8 40·9 ...	11 43·3 ...	−2·4
(3)	Baldwin	8 38·7 ...	11 41·1 ...	−2·4
(4)	Sitka	8 39·5 ...	11 39·8 ...	−0·3
(5)	Honolulu	8 42·7 ...	11 45·4 ...	−2·7
(6)	Mean of all	8 39·9 ...	11 41·9 ...	−2·0
(7)	Mean of Nos. 1, 2, 3.	8 39·10 ...	11 41·37 ...	−2·27
(8)	,, ,, 2, 4 ...	8 41·10 ...	11 42·60 ...	1·50

Difference No. 7–No. 8 −2·00 −1·23
Mean Difference ... −1·62

The average latitude for the two groups Nos. 7 and 8 is, respectively, 32° N. and 39° N., and the average longitude 79° W. and 147° W. It is accordingly found that this particular disturbance was propagated from stations in the eastern part of the United States to stations in the eastern Pacific Ocean about two and a half times slower than was found for the simple "S" disturbances, hence roughly at the rate of 2600 miles per minute, against 6700 miles for the latter cases. It is not to be assumed at present, however, that the big disturbances progress over the whole earth at a uniform rate. Their motions appear much more complicated than for the "S" cases.

Accordingly, so far as the big disturbances in general are concerned, the kathode-ray theory of Birkeland and Störmer fulfils the test regarding direction of progression of the disturbance over portions of the earth, and as far as the direction in which the negative electric currents must, in general, go, as found from the preliminary analyses above mentioned. Whether the theory will bear the application of quantitative tests cannot be discussed now. The main thing is to have working hypotheses to which rigid tests can be applied.

Should the electric-conduction theory above proposed to account for the disturbances there considered find further confirmation, the way is opened to a possible corpuscular theory of terrestrial magnetism. On the basis of such a theory, a number of the puzzling features of the distribution of the earth's magnetism and of its variations can readily be explained. L. A. BAUER.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

WE have received a copy of the "Livingstone College Year Book" for 1910. It contains college news, letters from old students detailing their experiences, a review of a year's progress in tropical medicine, &c. The training given at Livingstone College (a nine months' course) is designed to educate missionaries going to tropical countries in the elements of medicine, so far as they are required for the prevention of disease and the recognition and treatment of common accidents and diseases.

INDIANA UNIVERSITY, says *Science*, owns an experimental cave farm near Mitchell, Indiana, and has established a small laboratory there primarily for cave work. Cement pools have been placed inside and outside the caves, and give opportunities for breeding cave animals in the light and outside forms in the dark. The University offers a 100*l.* fellowship, in addition to a furnished cottage, to anyone who has had sufficient training to take up such work. Applications should be sent to Mr. F. Payne, Winona Lake, Indiana.

WE have received a copy of the handbook of the faculty of engineering at University College, London, for next session. The faculty includes the departments of mechanical, electrical, civil, and municipal engineering, and is intended to provide a systematic training for students who wish to devote themselves to engineering. It has been recognised by the Board of Trade as providing suitable technical training for marine engineers, and its courses also meet the needs of students who intend to enter for engineering appointments in the various public services. Prof. J. A. Fleming, F.R.S., is the dean, and Prof. J. D. Cormack the vice-dean, of the faculty.

THE governing body of the Imperial College of Science and Technology at South Kensington last year awarded two scholarships for research in connection with aëronautics. The students have held their scholarships at the National Physical Laboratory at Teddington. We learn from the *Times* of August 5 that an additional scholarship is now being offered for award at an early date by the governors of the college. The scholarship will be tenable for one year, and will consist of exemption from fees, together with a maintenance allowance at rates fixed with regard to the circumstances of the case, the value of the scholarship being not less than 50*l.* and not more than 150*l.* a year. It is open to any properly qualified individual, irrespective of residence or place of education. At Regent Street Polytechnic, too, the courses in aëro-engineering are to be developed. A second-year course of aërodynamics is being arranged for students who have qualified in the first year's work in aëro-engineering inaugurated during last session. The course will be open to other persons who can provide evidence that they possess the requisite knowledge of applied mathematics. Special instruction in workshop practice relating to aëroplanes and airships will be given, and students will receive help in making gliders and working models of different types of aërial craft they may be interested in.

THE calendar of the Edinburgh and East of Scotland College of Agriculture for 1910–11 provides full information as to the courses of instruction offered to pupils for the coming session. The college was founded in 1901 with the object of providing for agricultural education and research in the central and south-eastern counties of Scotland. Its classes are arranged in conjunction with certain classes in the science faculty of Edinburgh University. Courses for the diploma of the college and for the science degree of the University are concurrent. A short course, specially arranged to suit those who are actively engaged in farm work, is held at the college annually. The college also maintains a comprehensive scheme of extension work